POLYGENIC INHERITANCE OF YIELD COMPONENT CHARACTERS OF SOYBEANS

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RUH HWA MA

B.S., University of Nanking, China, 1935
M.S., University of Illinois, 1946

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IN THE GRADUATE COLLEGE OF THE
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R. UNIV. BIBLIOTHEEK LEIDEN

POLYGENIC INHERITANCE OF YIELD COMPONENT CHARACTERS OF SOYBEANS

Breeding for yield of farm crops is the most important problem for plant breeders. Since yield is a complex character with complex inheritance, it is determined by a polygenic system rather than by a few major genes for its phenotypic expression. Hence the importance of a better knowledge of polygenic inheritance can hardly be overestimated. Theoretically, the study of yield is facilitated by first resolving it into different component characters, and then by synthesizing into one plant genotype the combination of all desirable characters. Therefore the procedure seems to be to determine first the relationship of these characters to yield and then to investigate the genetical behavior of these component characters in order that a breeding program might be carried out most efficiently.

Yield of soybeans was resolved into six component characters as follows: height of plant, number of nodes per plant, number of pods per node, number of seeds per pod, average weight of 100 seeds or seed size, and the percentage of abortive seeds. The purpose of this study was to investigate the genetical behavior of the six component characters, which consists of following problems: mode of segregation, nature of gene action, components of genetic and non-genetic variances, percentage of heritability, degree of dominance, and estimation of effective number of genes involved in segregation.

Materials and Methods

Four varieties of soybeans (*Glycine max*), Richland, Chief, Lincoln, and Patoka, were used as parents for the present study. These four varieties are all good in yield performance but they differ from one another in the six component characters.

Six possible crosses were made among these four varieties

in 1945. F_1 hybrids and parents were grown in 1946 in 6 single-rowed plots with spaced planting. F_2 generations and the parents of all six crosses were planted in 1947 in a randomized block design with three replicates. In 1948, 19 F_3 families and parents of each cross were planted in progeny hills. In 1949, sixty F_4 lines which included 10 lines of each cross, and the four parent varieties were arranged into an (8×8) lattice experiment with four replications.

Six component characters were estimated from individual plants for the parents, F_1 and also for segregating generations. Variance analysis technique was used for analyzing the six component characters of different generations. Means, standard deviations, coefficients of variation, regression and correlation coefficients were calculated from the data to describe the characteristics of parents, F_1, and segregating populations. Fisher, Immer and Tedin's method and also Mather's method were applied for estimating components of genetic and non-genetic variances and degree of dominance. Gene action was tested by Charles and Smith's tests; and the Castle-Wright formula was used for estimating the effective number of factors involved in segregation.

Experimental Results

Mode of Segregation and Variability:

The six component characters exhibited continuous variation in the parental lines, F_1 as well as in segregating generations and thus must be controlled by polygenes. A study of variability of F_1, F_2, F_3 and the parental lines brought out the following facts:

1. F_1 hybrids and parental lines had small c.v.'s indicating that the individuals within F_1 or parental lines were comparatively uniform and homogeneous.
2. F_1 and parental lines had approximately equal magnitude of c.v.'s, but had different mean values.
3. c.v. of F_2 generation was much larger than that of the

parental lines or of the F_1.

4. F_3 progenies had average c.v. between F_1 and F_2 in magnitude, i.e. smaller than F_2 but larger than F_1 in variability. The result was consistent for all six component characters.

5. The F_3 family means differed one from another significantly by F test.

These five facts were shown to be universally true for all six component characters studied, and therefore can be looked upon as evidence that these component characters were inherited and segregated definitely in a mendelian manner, or in other words, that the inheritance was particulate.

Comparison of Average c.v.'s of Component Characters:

The average c.v. for each component character was obtained from six crosses for different generations, F_1, F_2, F_3. The c.v. for F_1 which indicated the non-genetic variability only was found to be 10.2% for height of plant, 8.7% for number of nodes, 12.0% for pods per node, 5.4% for seeds per pod, 8.2% for seed size, and 37.1% for percentage of abortive seeds. The average c.v. of F_2 was found to be 14.9% for height of plant, 9.8% for number of nodes, 20.4% for pods per node, 8.3% for seeds per pod, 9.8% for seed size, and 66.2% for percentage of abortive seeds. The average c.v. of F_3 for each component character was approximately intermediate in size between those of F_1 and F_2. With respect to size of c.v., it was observed that the average number of seeds per pod had the smallest variability for all three generations F_1, F_2 and F_3, indicating that it was a most stable component character; while percentage of abortive seeds had the highest c.v., showing it to be most susceptible to environmental fluctuation, and hence its real genotype could not be identified easily.

Analysis of Phenotypic Variance of F_2 Generation:

The observed phenotypic variance of F_2 generation for six

component characters was analyzed into five components: namely, additive genetic variance, dominance, genic interaction, environmental variance, and interaction between heredity and environment. The former three components are collectively called genetic variance. It was found from this analysis that there was no interaction between heredity and environment for all six component characters studied. Gene action was shown to be additive in nature in differentiating all component characters except percentage of abortive seeds which showed consistent differences between observed and expected F_2 values in X^2 test, and hence some non-additive gene action was indicated in this component character.

Genetic and environmental variances for six component characters were estimated from F_2 and parental populations by the isogenic line method. The average percentage of genetic variance from six crosses was determined to be 53.2% for height of plant, 31.0% for number of nodes, 25.4% for pods per node, 50.9% for seeds per pod, 44.5% for seed size, and 19.5% for percentage of abortive seeds. Average percentage of genetic variance was also estimated from the correlation between F_3 plants and F_4 means and found to be 38% for height of plant, 21% for number of nodes, 34% for pods per node, 54% for seeds per pod, 38% for seed size, and 31% for percentage of abortive seeds. Percentages for number of nodes estimated by the two methods were not comparable, because the former represents the genetic variance of number of nodes of the main stem only, while that of the latter represents genetic variance of total node number including that on the branches. In general, seeds per pod had the largest proportion, and percentage of abortive seeds had the least proportion, of genetic variance.

Components of Genetic Variance — Heritability:

Since gene action was found to be additive in nature, the genetic variance of each component character was then analyzed into two portions, i.e. additive genetic variance, and dominance variance. The former component is the most

important part of the variance that contributes to the degree of resemblance of parent and offspring. Percentage of additive genetic variance to the total phenotypic variance is termed percentage of heritability in the narrow sense. Average percentage of heritability from two crosses, Chief × Richland, and Lincoln × Richland, the parents of which had marked differences in six characters was estimated to be 50.4% for height of plant, 24.8% for pods per node, 58.5% for seeds per pod, 30.4% for seed size, and 5.0% for percentage of abortive seeds. Heritability of number of nodes was not determined due to the reason that data of the character were not comparable in different generations.

According to size of genetic variance, number of seeds per pod and height of plant were ranked as "highly heritable" characters, while percentage of abortive seeds and number of pods per node were "highly environmental" characters.

Measurement of Dominance:

Dominance tendency of six component characters was investigated by computing the potence ratio and the S(h) value, and also by estimating $\sqrt{H/D}$ statistic which indicates the potential degree of dominance. Results obtained were summarized as follows: (1) The greater plant height was partially dominant to the lower in all six crosses. (2) No hydrids had fewer nodes than the parents, i.e. hybrid vigor was shown in all crosses. All of the S(h) values were positive in sign and three of them differed significantly from zero indicating probably that higher number of nodes was dominant over small number of nodes. (3) Number of pods per node showed either no dominance or partial dominnace toward the small number. (4) Large number of seeds per pod was partially dominant. (5) Very large potential dominance variance was found in seed size, but concerning the direction of dominance, large seed size was found dominant in two of the crosses, small seed size was found in one, and balanced dominance was found in the remaining three crosses. (6) Dominance tendency was not easily determined in percentage of

abortive seeds because of high variability of this character.

Effective Number of Genes:

It was estimated that about 6,2,2, and 5, grouped genes or effective number of genes controlled height of plant, number of pods per node, number of seeds per pod and seed size, respectively. The effective number of genes for number of nodes and percentage of abortive seeds was not determined because of small difference of the former between parntal lines and high variability of the latter. However, the numerous assumptions necessary in estimating the number of genes based on F_2, F_3 and parents, make the results obtained of little value.

Application to Selection Program:

With respect to the relative size of environmental variance and genetic variance, the six component characters of soybeans can be grouped into two classes. The first which includes number of seeds per pod, height of plant, and seed size, had rather low environmental variance; while the second class which includes percentage of abortive seeds, number of pods per node, and number of nodes, had high environmental variance. It is generally known that selection of the desired genotype is made more and more uncertain as the environmental variance of the total variance increases in proportion to the genetic portion. Therefore the selection of individuals possessing characters of the first class is more effective than selection of individuals possessing characters of the second class. In order to breed for high yielding varieties of soybeans, it is suggested that the more stable component characters be concentrated on for improvement first, because they are less affected by environmental fluctuation, and hence the desired genotype can be more easily recognized in the selection process.

VITA

The author was born on October 12, 1912, in a small village in Kwantung, China. In January, 1935, he graduated from the University of Nanking, Nanking, China, with the degree of Bachelor of Science. After graduation, he was appointed research associate in the Department of Agronomy, University of Nanking, from January, 1935, to May, 1939. He was promoted to an instructor from June, 1939, to May, 1942; and to assistant professor from June, 1942, to March, 1945. In January, 1945, he passed the qualifying examinations given by the Examination Yuan and the Ministry of Agriculture of Chinese Government, and finally was awarded a fellowship sponsored by the Bureau of Foreign Economics of U.S. government. He arrived in United States in May, 1945, and was assigned to make survey and study on soybean improvement and production in agricultural experiment stations of twelve states. Meantime, he matriculated in the Graduate College of University of Illinois, and was awarded the degree of Master of Science in June, 1946. Since then, he was asked by the University of Peking, Peking, China, to serve as an associate professor and acting head of Department of Agronomy. In September, 1947, he resigned and came to Canada to receive a research fellowship awarded by the University of Saskatchewan, Saskatchewan. In August, 1948, he returned to University of Illinois to continue his graduate studies, and held a University Fellowship for two academic years 1948-1950.

He is a life member of The Agricultural Association of China, a member of American Society of Agronomy,

American Soybean Association, American Association for Advancement of Science. He was elected an active member by the Phi Kappa Phi and Sigma Xi honorary societies.

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